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MATERIALS EXPERIMENT CARRIER CONCEPTS DEFINITION STUDY PART 2

VOLUME III

PROGRAMMATICS

TRW CONTRACT NO. NAS8-33688

17 DECEMBER 1981

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

ALABAMA 35812

TRW

DEFENSE AND SPACE SYSTEMS GROUP
ATTACHED SHUTTLE PAYLOADS ORGANIZATION
ONE SPACE PARK • REDONDO BEACH • CALIFORNIA 90278

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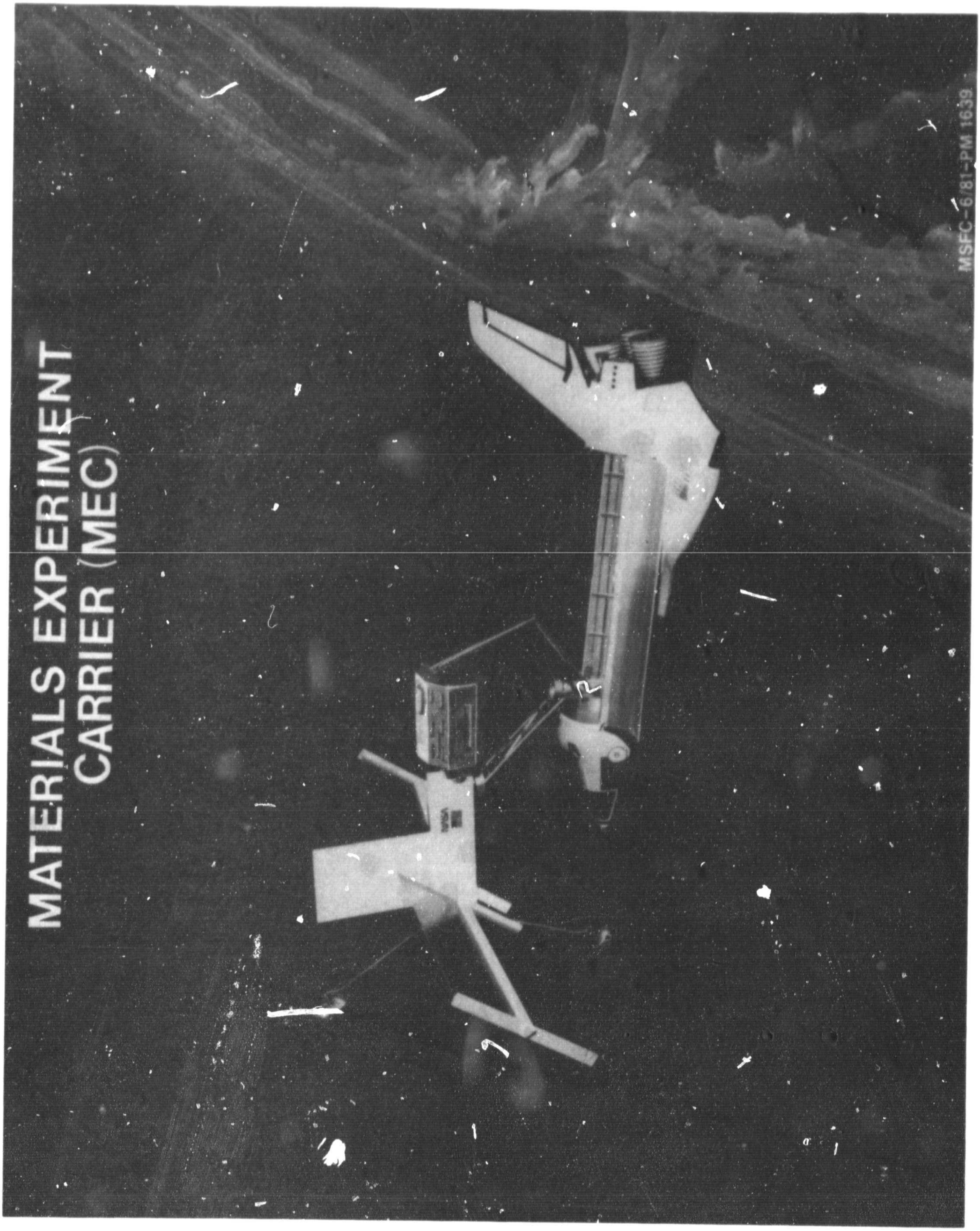

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1.0 INTRODUCTION

The specific objective of the Materials Experiment Carrier (MEC) Study Task 4, Programmatics, was to derive project logic, schedule and funding information needed by NASA to enable decisions to be made regarding implementation of MEC system development.

In the MEC Concepts Definition Study, Part 1, a master schedule and cost and price estimates (ROM) were developed for a project that consists of development of an all-up* MEC, its integration with payloads and its flight on one 90 day mission. In Part 2 of the study a simpler initial MEC was defined to accommodate three MPS baseline payloads. Figures 1, 2 and 3 illustrate the proposed design of this initial MEC. The project logic and the new, more detailed schedules and ROM cost estimate relate to a project in which this initial MEC is developed, integrated with payloads and flown once for 180 days. All of the material in this volume is concerned with this initial MEC.

In the development of these programmatic materials we have attempted to surface all of the important considerations, in a project of this type, that relate to its successful achievement. This aspect is discussed in more detail in Section 2, Programmatic Considerations.

Acknowledgement is made of the important contributions made to the MEC Programmatic results by:

1. Mr. Gerald A. Wheeler of the Engineering Cost Group, Program Planning Office, Program Development of the NASA/Marshall Space Flight Center, Alabama and
2. Mr. Norman D. Redlich, Manager of Project Pricing, Attached Shuttle Payloads Organization, TRW, DSSG, Redondo Beach, California

*Carries eight payloads, serviceable on orbit

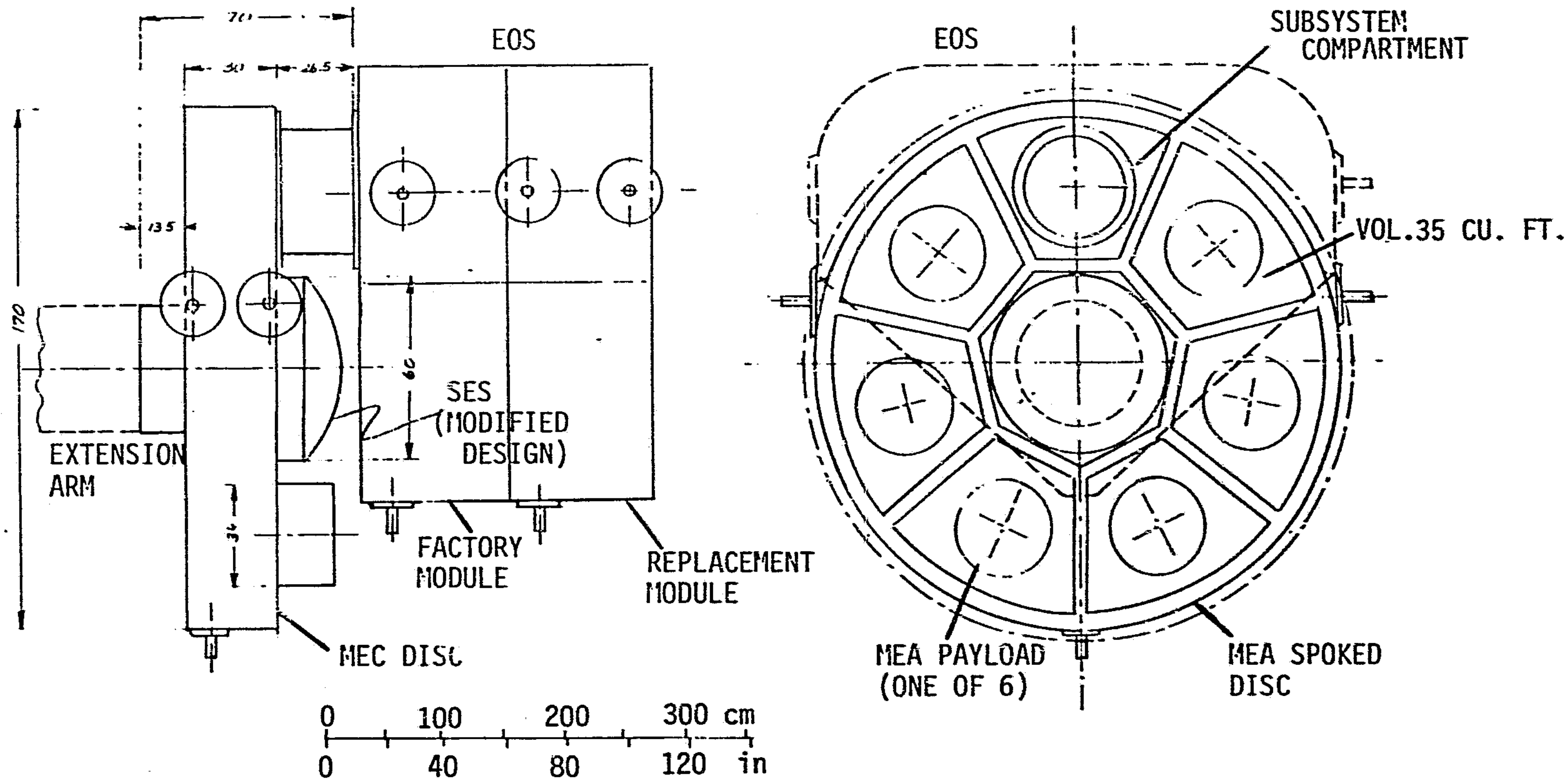
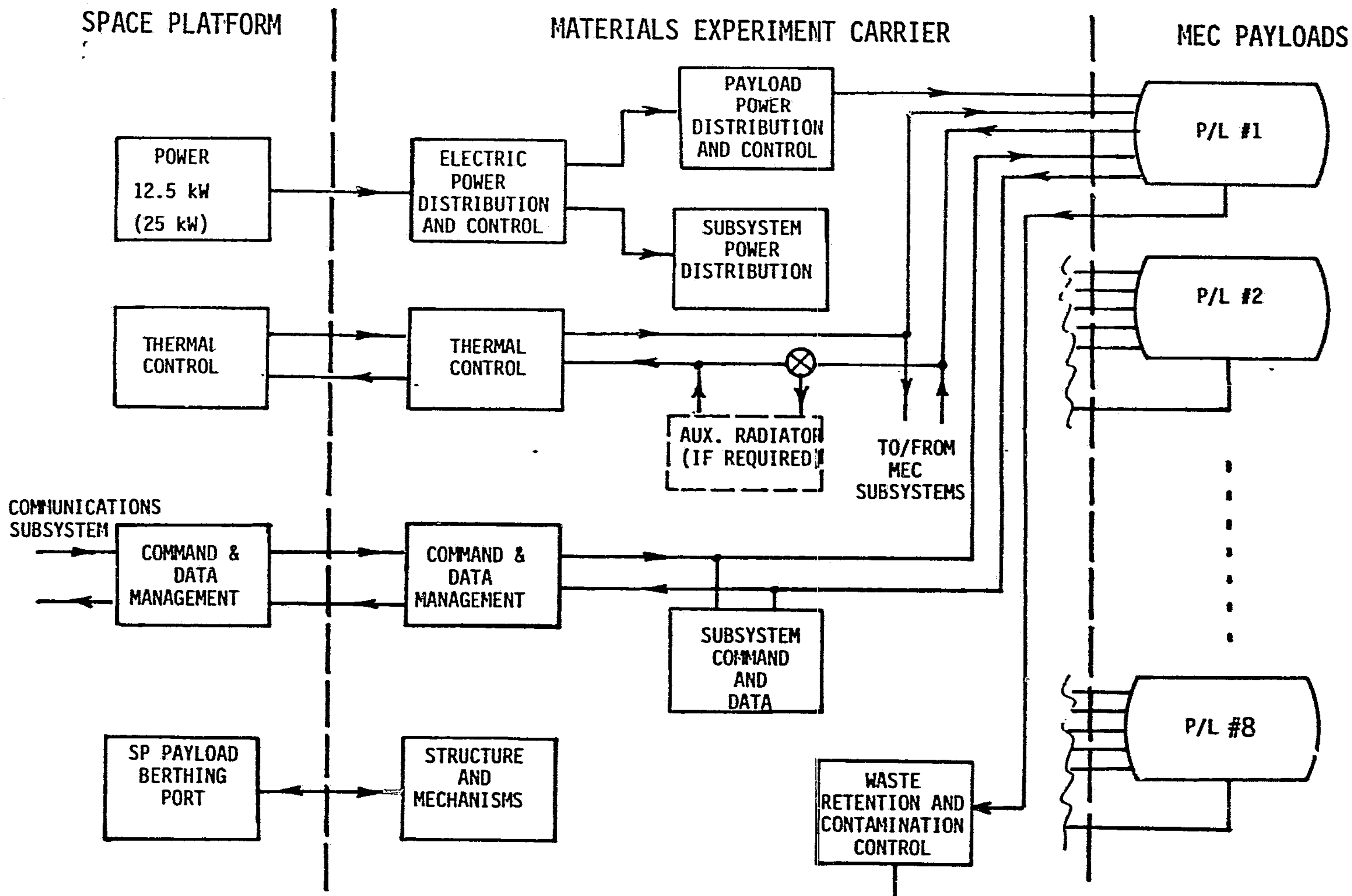


Figure 1. Initial MEC Configuration, Including EOS



NOTE: DOES NOT INCLUDE MEC/ORBITER INTERFACES

Figure 2. Summary Functional Block Diagram for Initial MEC

2.0 PROGRAMMATIC CONSIDERATIONS

In the development of the schedules and cost estimates a number of assumptions and groundrules were stated in order to provide definition and bounds to the estimates. Some of these relate to design and are listed in Figure 3 (Key Design Factors for Initial MEC). Other relate to the process by which design, development and operation of the MEC could be brought about; these are listed in Figure 4 (MEC Project Logic). For further MEC definition activity, it is important that these types of programmatic considerations be examined and questioned in context with the whole MPS program. This is to assure that the next phase of MEC development be guided as befits a progressive project definition. The following illustrate this point:

a. What are the specific payloads and their definitive requirements on MEC? We assumed certain characteristics for SES (repackaged), EOS, and six MEA facilities, identical as far as MEC interfaces are concerned. Obviously as the development of these payloads progresses, their requirements on MEC will change. Further there will be subsequent MEC flights with new MPS payloads, so far not selected or defined. The services that MEC provides to payloads must be fixed at some time. Thought should be given to when that time should be in the MPS program.

b. When will the MEC project hardware start occur relative to Space Platform start? We have assumed that SP technology and component specifications will be available to MEC in time for the MEC PDR. Without this prior development work, MEC costs will increase.

c. How autonomous will the payloads be? We assumed that payloads are self sequencing, and provide their own heat exchanger, gas supplies, and sample storage and handling. Some overall program cost savings might accrue if MEC were to provide some centralized services.

d. Where will the MEC payload integration site be located? We assumed it to be at the MEC contractors plant, thus no capital cost to the government. There are moves toward having this sort of activity be performed in the KSC/Cape Canaveral area to avoid shipment of large integrated Shuttle payloads long distances. NASA should explore this problem in its full context.

e. What are the ground operations turn-around time between flights requirements on MEC? We assumed that no extrordinary measures would be taken to assure that the MEC can accomplish a six month turn-around to meet the postulated revisit interval for the Space Platform. It is likely that such a turn-around can be accomplished. However, it might be necessary to make that a project level requirement, which would assure an increase in the MEC cost. A more definitive understanding of experimentation rate in the MPS program is needed in order to know if such a step is justified.

SYSTEM

- MEC STRUCTURE IS A MODIFIED ADVANCED MEA SPOKED DISC CONFIGURATION
- NO IN-FLIGHT SERVICING DURING THE ONE-HUNDRED EIGHTY DAY OPERATIONS
- REFURBISHED ON GROUND BETWEEN MISSIONS
- CAPABLE OF EVOLUTIONARY GROWTH TO ALL-UP MEC
- CARRIES SES, SIX MEA PAYLOADS, AND EOS. PAYLOADS HIGHLY AUTONOMOUS

SUBSYSTEMS

1. COMMAND AND DATA MANAGEMENT

- CDMS CONTROLS MAJOR MEC OPERATING MODES
- PAYLOADS DO OWN SEQUENCING, UNDER CDMS EXECUTIVE CONTROL
- CDMS DOES DATA PACKETIZING AND LIMITED DATA PROCESSING
- DETECTS MALFUNCTIONS AND COMMANDS CUT OFF TO SAFEGUARD SYSTEM

2. ELECTRICAL DISTRIBUTION

- HANDLES FULL SPACE PLATFORM (SP) POWER
- PROVIDES FULL POWER TO ALL PAYLOADS
- PROVIDES KEEP-ALIVE CAPABILITY WITH AUXILIARY BATTERY SYSTEM

3. THERMAL CONTROL

- SP PROVIDES HEAT REJECTION COMPARABLE TO POWER DRAWN, NO MEC RADIATOR
- TCS TRANSFERS HEAT FROM PAYLOADS TO SP AS REQUIRED

4. STRUCTURE AND MECHANISMS

- STANDARD SP BERTHING PORT AND ADAPTER WILL BE USED
- DYNAMIC RESPONSE OUTSIDE ORBITER NATURAL FREQUENCY RANGES

Figure 3. Key Design Factors for Initial MEC

THE MEC SCHEDULES AND ROM COST ESTIMATE ARE BASED ON THE FOLLOWING PROJECT LOGIC:

REQUIREMENTS

- PAYLOADS WILL BE SUFFICIENTLY DEFINED THAT PROGRAM AND HARDWARE REQUIREMENTS CAN BE DEFINITIVELY STATED IN THREE MONTHS AFTER GO-AHEAD

DESIGN AND DEVELOPMENT

- SPACE PLATFORM DEVELOPMENT WILL PRECEDE MEC BY AT LEAST 10 MONTHS
- NO NEW TECHNOLOGY DEVELOPMENT REQUIRED TO PERFORM MAJOR MEC FUNCTIONS
- SUBSYSTEM COMPONENTS WILL HAVE BEEN QUALIFIED FOR SPACE FLIGHT ON SPACE PLATFORM, SHUTTLE, SPACELAB OR OTHER PROJECTS.
- CRITICAL ELEMENTS OF THE SUBSYSTEMS WILL BE BREADBOARDED AND DEVELOPMENT TESTED AS SYSTEMS
- STRUCTURE WILL BE NEW AND UNIQUE

INTEGRATION AND TEST

- THE PROTOFLIGHT DEVELOPMENT CONCEPT WILL BE USED. STRUCTURE VERIFICATION TESTS WILL BE PERFORMED BY USING THE FLIGHT STRUCTURE, WITH DUMMY MASSES FOR PAYLOADS.
- NO ALL-UP THERMAL VACUUM TEST WILL BE PERFORMED. EXTRA CAPACITY WILL BE BUILT INTO THE ACTIVE THERMAL CONTROL SYSTEM
- MEC INTEGRATED SYSTEM TESTS WILL BE PERFORMED USING SIMULATED PAYLOADS

GROUND OPERATIONS

- PAYLOADS WILL BE THOROUGHLY TESTED AGAINST A MEC INTERFACE SIMULATOR PRIOR TO INTEGRATION.
- PAYLOADS WILL BE INTEGRATED WITH MEC AT THE MEC CONTRACTORS' PLANT
- MEC, INTEGRATED WITH PAYLOADS, WILL BE TESTED AGAINST A GFE SPACE PLATFORM INTERFACE SIMULATOR PRIOR TO STS INTEGRATION

FLIGHT OPERATIONS

- MEC CONTRACTOR WILL PROVIDE FLIGHT OPERATIONS SUPPORT SERVICES

Figure 4. MEC Project Logic

3.0 SCHEDULES

3.1 OVERALL PROJECT SCHEDULE

The full schedule for the MEC development and operations project is shown in Figure 5. In Part 1 of this study a 36 month time from contract start to launch was postulated. During Part 2 of the study individual activities were examined in more detail. Following are a number of waterfall charts of these activities. The outcome is a more conservative approach and a time of 48 months to launch. The schedule includes a 180 day flight duration which makes the total project time 57 months instead of the 42 months in the schedule developed during Part 1.

3.2 MANUFACTURING SCHEDULES

Figure 6 depicts the manufacturing schedules for each subsystem and for the ground support equipment.

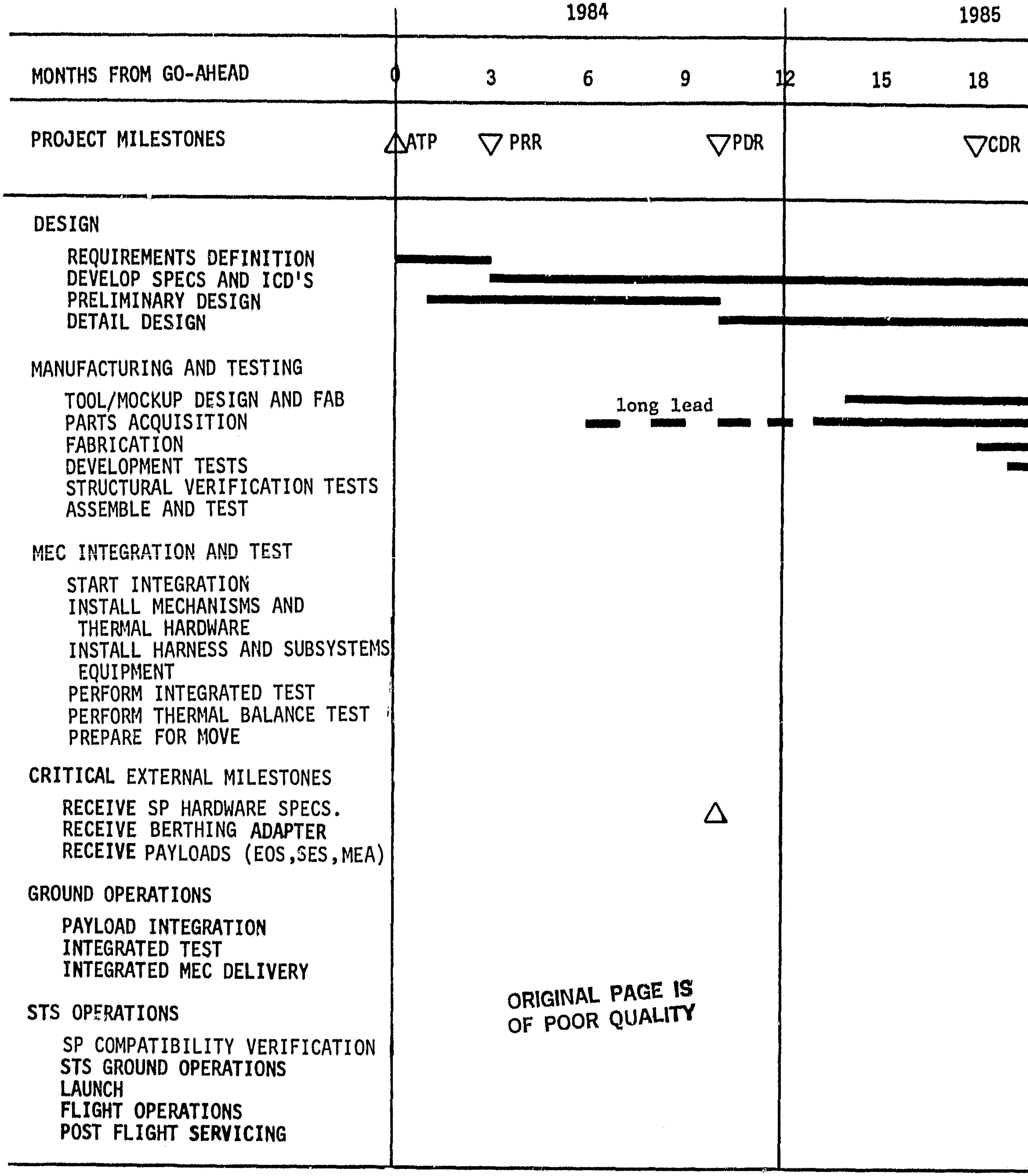
These major activities are keyed to the integration and test need dates for each set of hardware items. Some long lead parts acquisition or fabrication must be started prior to PDR. This is not uncommon for projects of this size and is usually more cost effective than taking the other alternative of extending the time for the whole project.

3.3 INTEGRATION AND TEST

The integration and test of the MEC vehicle is depicted in Figure 7. It starts with subsystem elements provided from manufacturing as needed and ends with the MEC assembled, tested, and ready for movement to the payload integration site. This is a point where the government could buy-off the vehicle from the development contractor. All major tests required for this buy-off, are scheduled here or during manufacturing. The validation and test plan is discussed in Volume II, Section 6.4.2.

It should be noted that the thermal control system is assembled and tested for the first time, as a flight system, during vehicle integration. This is in contrast to electrical and CDMS subsystems that can be tested adequately prior to final assembly in the vehicle.

The duration of the I&T functions is about 159 days or 32 five day work weeks.


1984
1985
MONTHS FROM GO-AHEAD
0
3
6
9
12
15
18
PROJECT MILESTONES
ATP
PRR
PDR
CDR
DESIGN
REQUIREMENTS DEFINITION
DEVELOP SPECS AND ICD'S
PRELIMINARY DESIGN
DETAIL DESIGN
MANUFACTURING AND TESTING
TOOL/MOCKUP DESIGN AND FAB
PARTS ACQUISITION
FABRICATION
DEVELOPMENT TESTS
STRUCTURAL VERIFICATION TESTS
ASSEMBLE AND TEST
long lead
MEC INTEGRATION AND TEST
START INTEGRATION
INSTALL MECHANISMS AND THERMAL HARDWARE
INSTALL HARNESS AND SUBSYSTEMS EQUIPMENT
PERFORM INTEGRATED TEST
PERFORM THERMAL BALANCE TEST
PREPARE FOR MOVE
CRITICAL EXTERNAL MILESTONES
RECEIVE SP HARDWARE SPECS.
RECEIVE BERTHING ADAPTER
RECEIVE PAYLOADS (EOS,SES,MEA)
GROUND OPERATIONS
PAYLOAD INTEGRATION
INTEGRATED TEST
INTEGRATED MEC DELIVERY
STS OPERATIONS
SP COMPATIBILITY VERIFICATION
STS GROUND OPERATIONS
LAUNCH
FLIGHT OPERATIONS
POST FLIGHT SERVICING

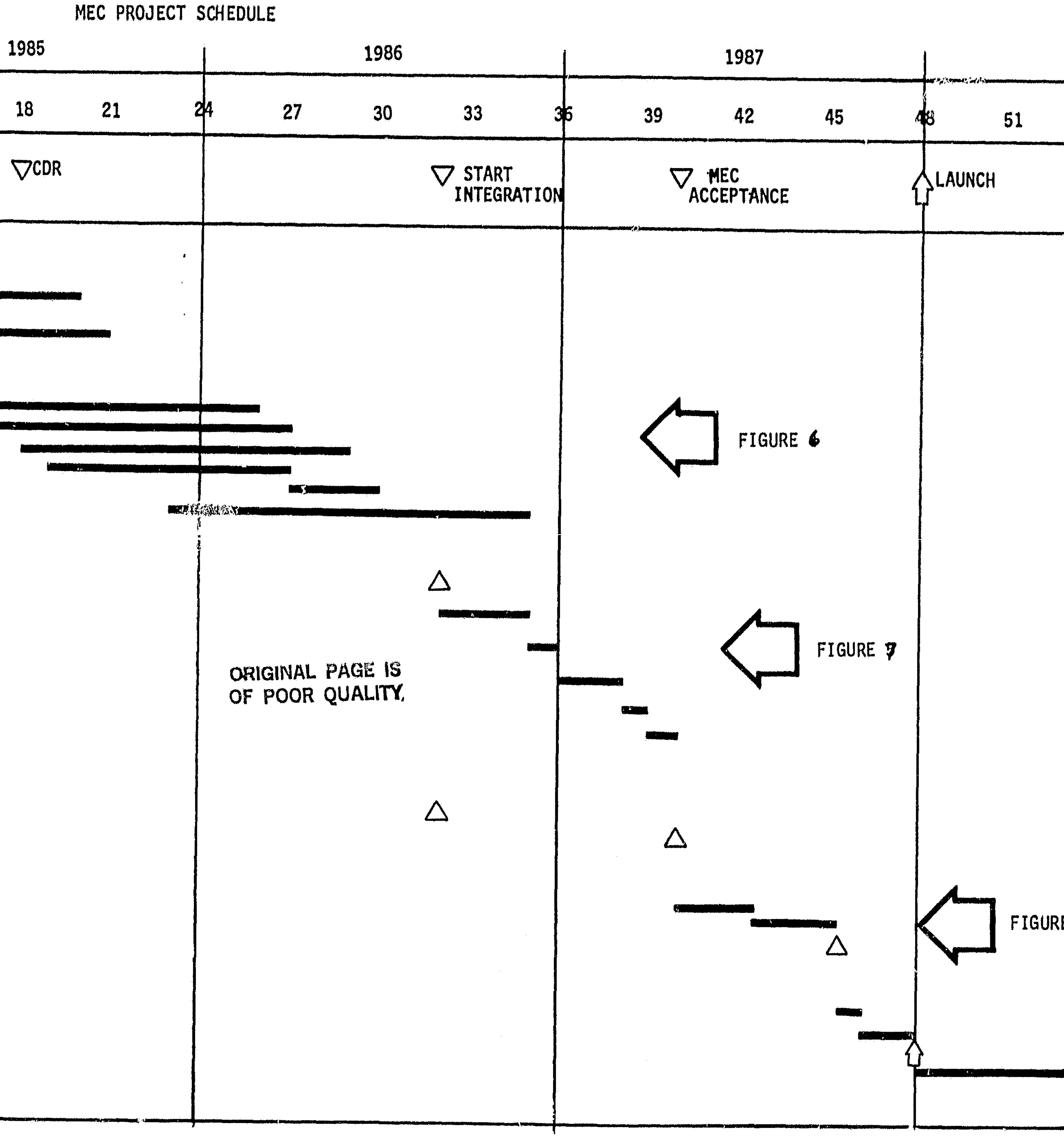


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Figure 5. Initial MEC Project Sched

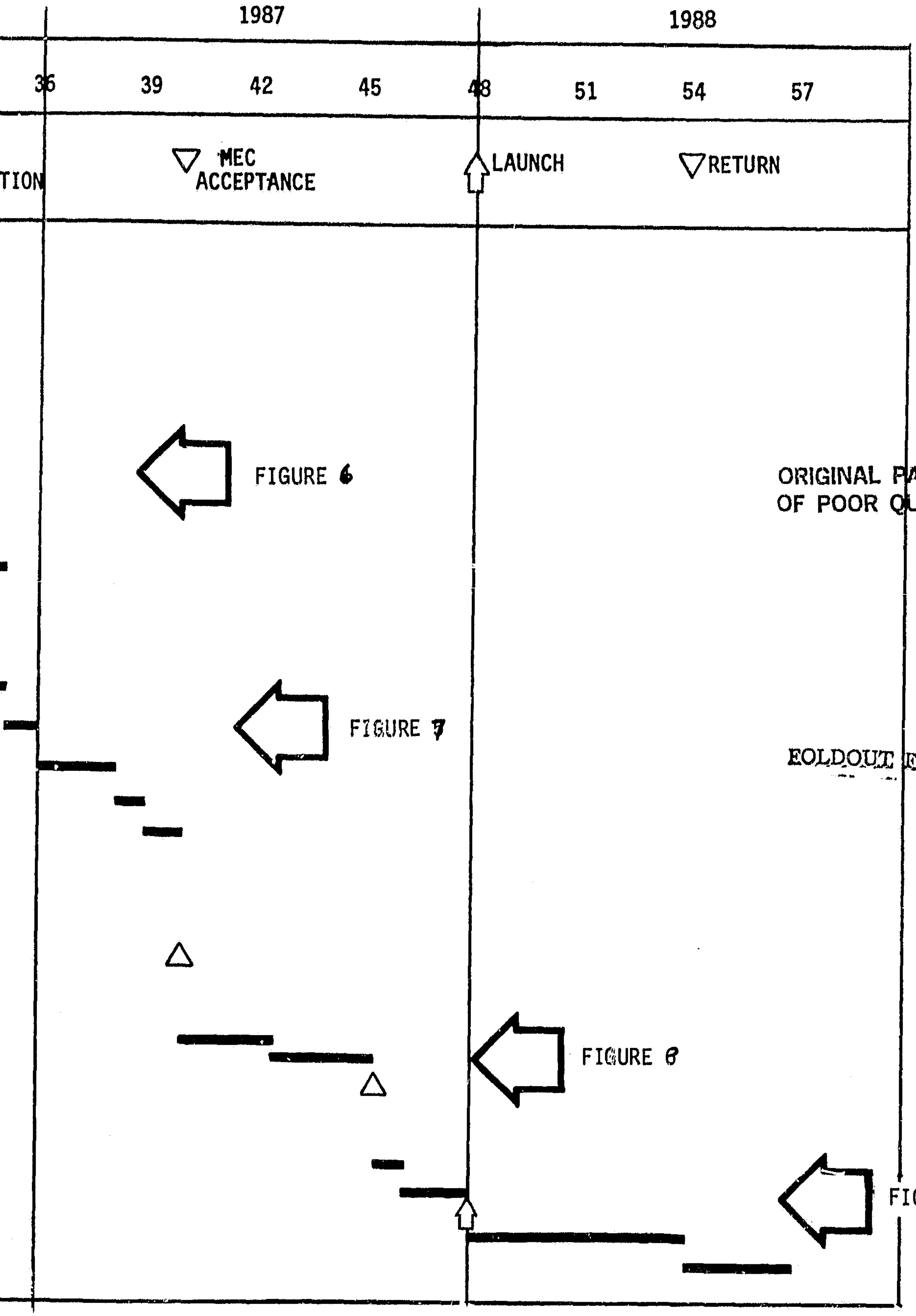

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Figure 5. Initial MEC Project Schedule

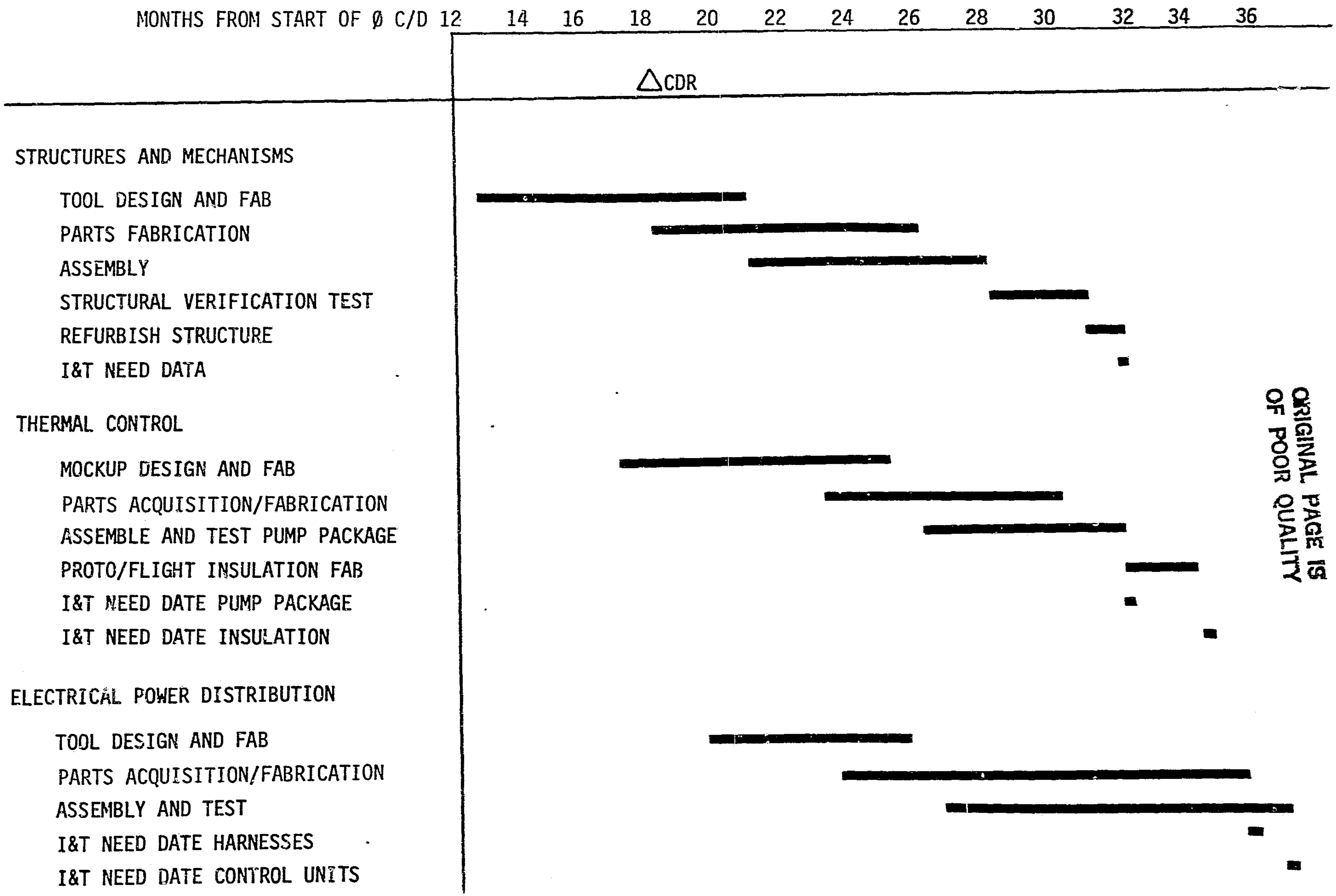


Figure 6. Manufacturing Schedules

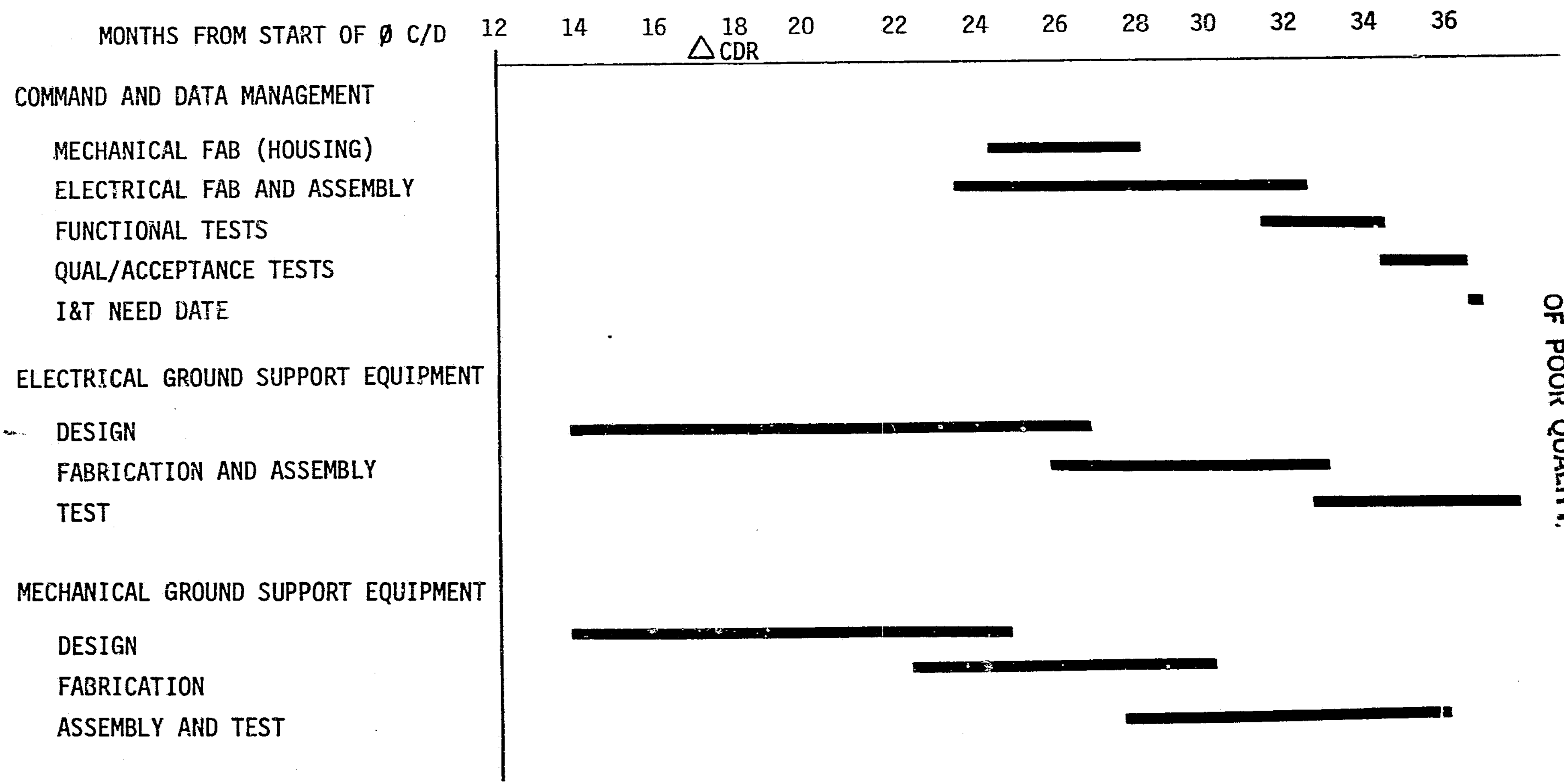


Figure 6. Manufacturing Schedules (Continued)

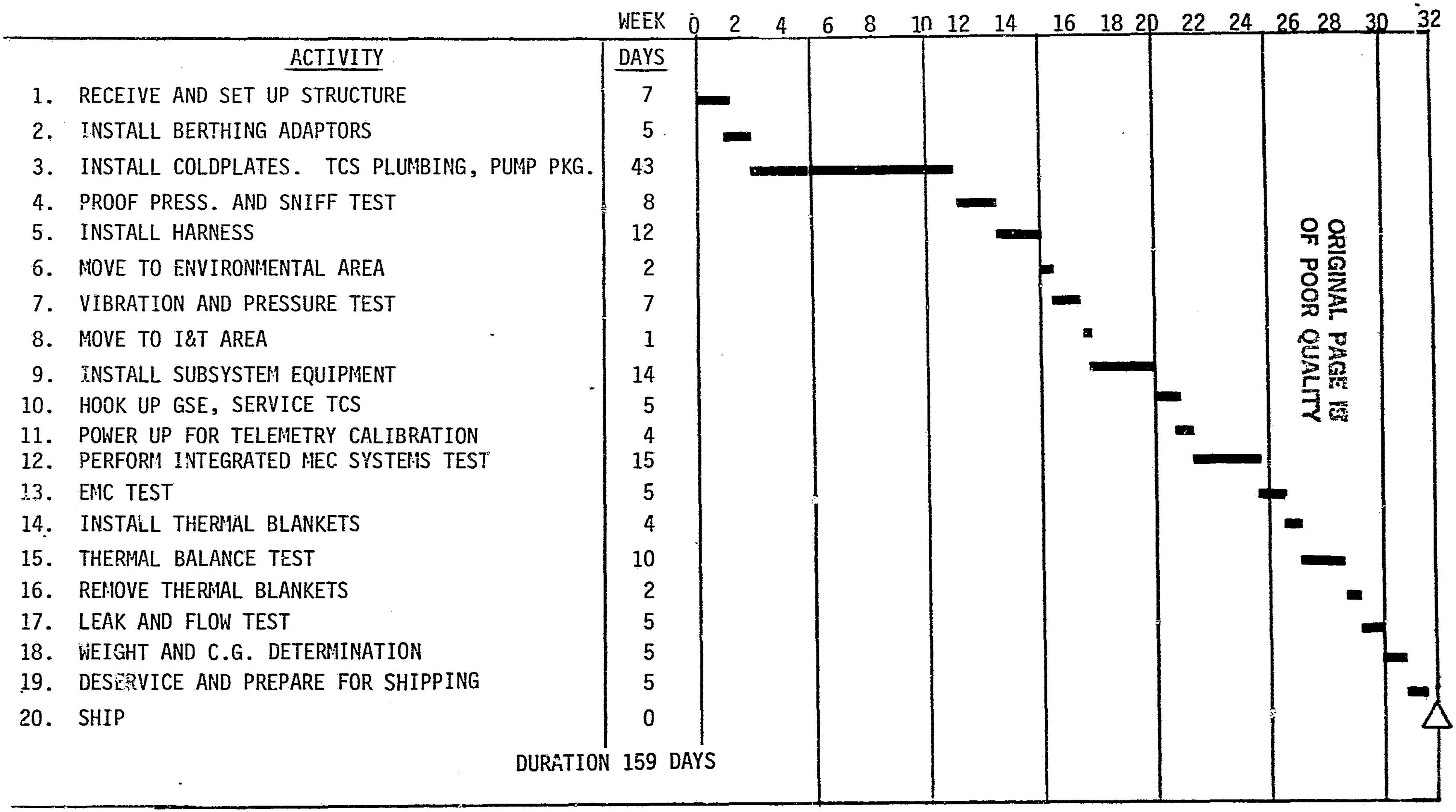


Figure 7. MEC Integration and Test Waterfall

3.4 GROUND OPERATIONS

Ground operations are differentiated from MEC integration and test because they are recurring for each flight.

The activities for integration of the payloads with the MEC are shown on Figure 8. This function starts with the MEC delivered from integration and test and with payloads that were previously tested operationally against a MEC simulator. Without this off-line compatibility verification of the payloads the duration of the integration function would be considerably extended. This function ends with the MEC and payloads ready to enter STS ground operations. The duration is about 960 hours or 24 forty hour weeks.

All of the MEC ground operations are related on the schedule shown in Figure 9. Following delivery of the integrated MEC, it is expected that a Space Platform compatibility verification test will be required. This test, although performed off-line to Shuttle cargo integration, is in line for MEC. It is estimated to take about 238 hours the first time it is performed with about a 30% improvement in subsequent tests. For the present MEC schedule three weeks of calendar time is used representing a first run, with two shift (80 hours per week) operation.

In K-CM-03.2 "Cargo Projects, Schedules, and Status Summary," of January 31, 1981 KSC has provided detailed scheduling for STS cargos through 1984. It is found that the integration times for non-boosted payloads quickly converge to the following intervals.

CLASS	EXPERIMENT INTEGRATION	CARGO INT. & LAUNCH PREP. (WEEKS)	TOTAL TO LAUNCH
Spacelab	12	7	19
LDEF (First TIME)	11	4	15
Other "Pallets"	8	5	13

The seven week cargo integration and Shuttle launch preparation time was taken for MEC and so shows some STS operational maturity.

It should be noted that MEC ground operations overall use about 8 months which is longer than the postulated SP revisit cycle time of

		HOURS
1.	RECEIVE MEC, MOVE, REMOVE	10
2.	RECEIVING INSPECTION	10
3.	INSTALL MEC AND PREPARE	30
4.	PAYLOADS, RECEIVE, MOVE, INSPECT	14(EA)
5.	INSTALL PAYLOADS ON MEC, VERIFY INTERFACES	198
6.	INSTALL AND CHECKOUT SERVICE GSE	4
7.	SERVICE PAYLOADS AND CHECK FOR OPS. READINESS	75
8.	DISCONNECT SERVICING GSE	2
9.	CONNECT INTERFACE CABLES AND LINES	42
10.	LOAD SOFTWARE AND PREPARE GSE	95
11.	PERFORM FUNCTIONAL INTERFACE TESTS	118
12.	VERIFY SOFTWARE COMPATIBILITY	60
13.	PERFORM COMBINED SYSTEM TEST	192
14.	CONDUCT OPEN ITEM REVIEW	24
15.	DESERVICE, DEMATE	30
16.	MOVE, PREPARE FOR SHIPPING	61
17.	SHIP	

DURATION 960 HRS

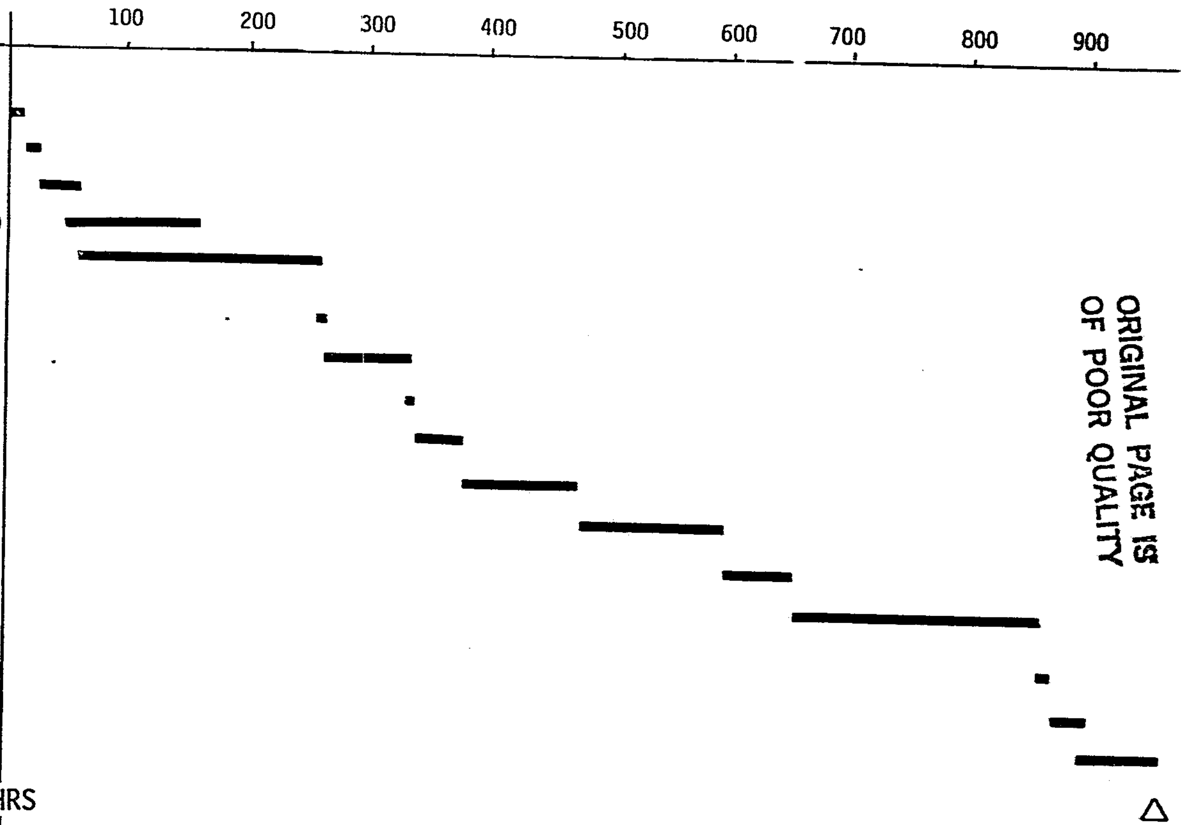
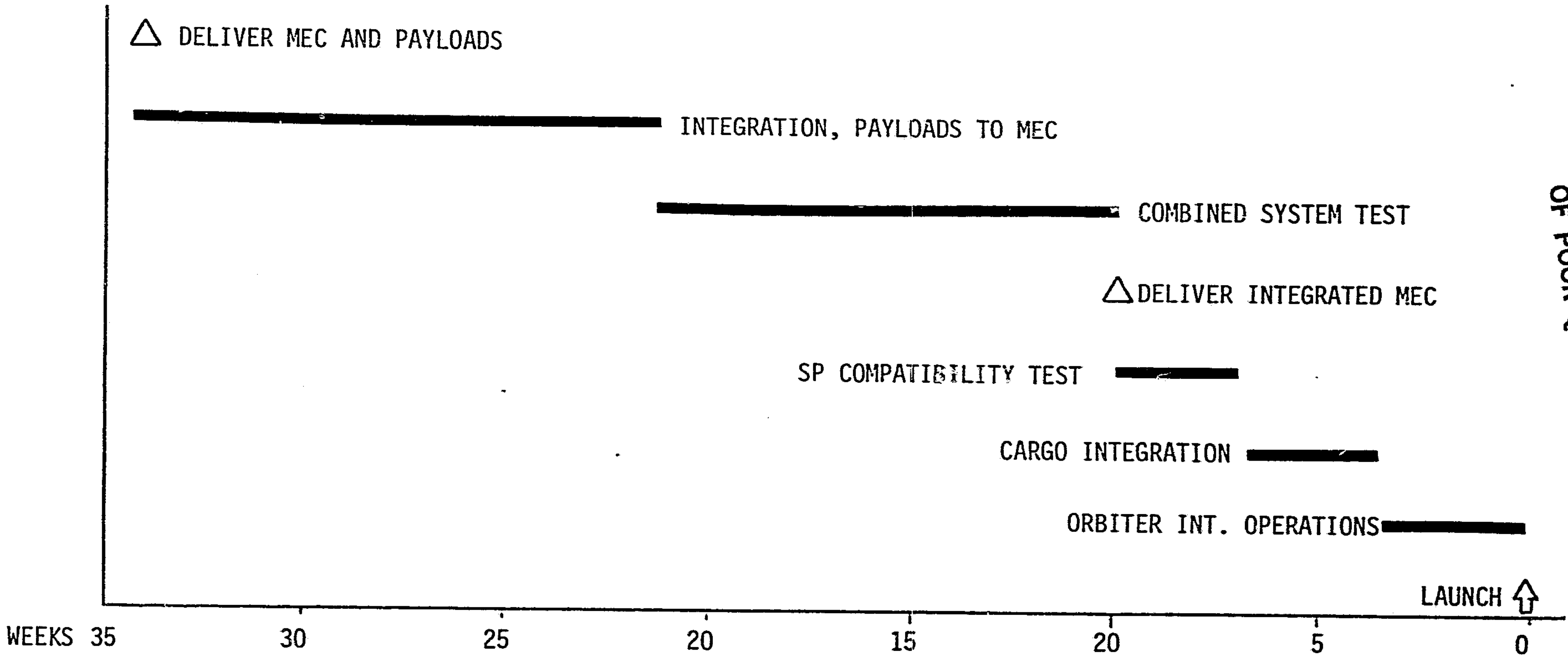


Figure 8. MEC/Payloads Integration and Test Waterfall



Notes:

- o TIMES ARE FOR FIRST MEC OPERATION
- o MEC/PAYLOAD OPERATIONS AT 40 HR/WEEK
- o STS OPERATIONS USE 80 HR/WEEK

Figure 9. MEC Ground Operations

6 months. Further, no time is blocked out for modification or refurbishment of the MEC between flights. Some time will be gained after repeated performance of the integration activities, however, the MEC design and program thinking should respect the fact that ground operations time between flights is a major item of concern. A careful delineation of these activities must be made during Phase B of the MEC project, after a more detailed design is available and with a firm definition of the early payloads.

4.0 MEC PROJECT COST ESTIMATE

The project costs presented here are for a MEC project in which an initial capability MEC is developed, integrated with payloads, flown once and the data are reduced to a form usefull to the investigators.

The costs are presented for each element of the Work Breakdown Structure shown in Figure 10. Tasks described in the WBS dictionary, developed previously, are applicable to this WBS with the exception that some level 5 elements were grouped and estimated at level 4. There are also a few instances where level 5 tasks were distributed. This estimate does not include costs for payload development, investigator support, STS charges or Institutional Management Support.

A number of programmatic assumptions have been made that directly effect costs. These are listed in Figure 4 "MEC Project Logic" (page 6). One MEC flight article will be built. Other deliverable, support, equipments are listed in Figure 11.

The cost estimates were developed by individuals who are well experienced in the particular activities. They made use of actual cost data from TRW projects or, where more appropriate, data from phase B studies. These data were factored for differences in complexity between the reference system and MEC or where applicable for differences in quantities. These bases of estimates are listed in Figure 12. All estimates were reviewed by functional management and were modified, where appropriate, on the basis of their experience. It will be noted that much use was made of Space Platform data. This is because much of the technology required for MEC is expected to have been developed by the Space Platform project. The exact method by which these data were used is sufficiently diffuse that no A109 sensitive data is revealed.

The cost estimates by WBS element are shown in Figure 13. These are expressed in 1982 dollars, per MSFC instruction. It should be noted that the figures represent cost to the government, as fee has been distributed into the elements. It will also be noted that an additional cost element has been included, 012 Management Reserve, which was established by TRW management, at 20% of the total project costs.

Figure 14 shows an assembly of the costs by Design and Development (non-recurring), Unit (recurring if additional units are procured) and Operations (recurring for additional flights). Figure 15 is a spread of the costs in real-year dollars. A 9% per year inflation rate was used and the project start was January 1984, both were MSFC instructions.

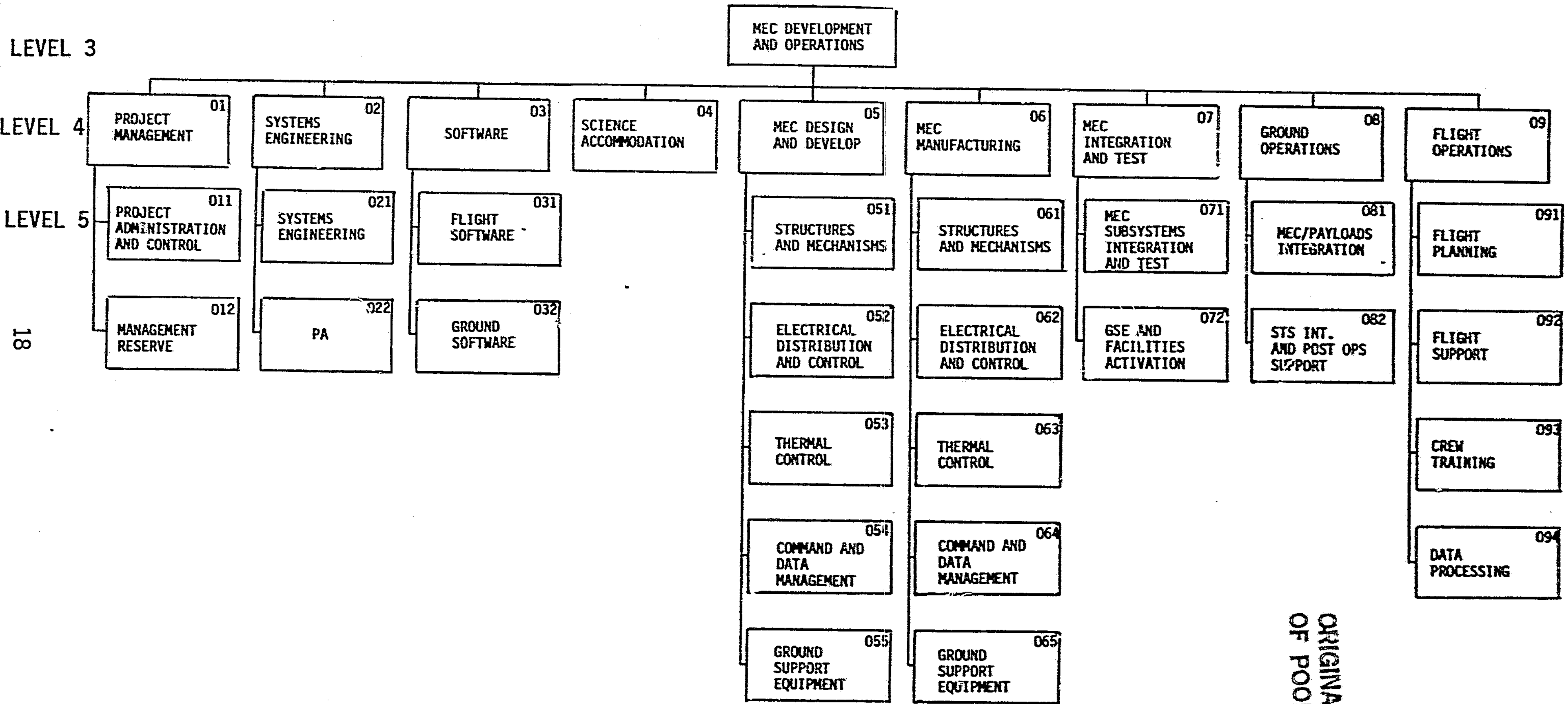


Figure 10. MEC Project Work Breakdown Structure
As Used in this Cost Estimate

DEVELOPMENT

- THERMAL CONTROL SYSTEM TEST BRASSBOARD
- CDMS DEVELOPMENT SYSTEM
- ELECTRICAL CONTROL SYSTEM BREADBOARD

MANUFACTURING

- TUBING FABRICATION MOCKUP
- WIRE HARNESS FABRICATION FIXTURES

INTEGRATION AND-TEST

- STRUCTURAL TEST FIXTURES
- ASSEMBLY FIXTURE
- THERMAL TEST SET
- ELECTRICAL SUPPLY CART
- THERMAL SYSTEM SERVICING CART
- SYSTEM TEST SET

OPERATIONS

- SLINGS AND SHIPPING CONTAINERS
- PAYLOAD INTEGRATION STAND
- INTEGRATED SYSTEM TEST SET
- MEC INTERFACE SIMULATOR (PAYLOAD TEST SYSTEM)
- PCC SET (MEC PECULIAR)

Figure 11. Major Support Equipment

01 PROJECT MANAGEMENT

011 PROJECT ADMINISTRATION AND CONTROL

≈ 10% OF ALL PROJECT COSTS. BASIS: TRW LOCOST MODEL

012 MANAGEMENT RESERVE, 20% OF TOTAL. BASIS: MANAGEMENT JUDGEMENT

02 SYSTEM ENGINEERING

021 SYSTEMS ENGINEERING

≈ 10% OF PROJECT COSTS. BASIS: TRW LOCOST MODEL

022 PRODUCT ASSURANCE INCLUDES QUALITY CONTROL

≈ 10% OF PROJECT COSTS. BASIS: TRW LOCOST MODEL

03 SOFTWARE. BOTH FLIGHT AND GROUND SOFTWARE ESTIMATED TO HAVE 6000 LINES OF CODE EACH. 12000 LINES TOTAL. RECENT EXPERIENCE WITH SPACE SYSTEM SOFTWARE INDICATES CODING RATE OF 1.5 HRS/LINE. BASIS: SIMILAR SOFTWARE FOR EARTH RESOURCES BUDGET EXPERIMENT (ERBE).

04 SCIENCE ACCOMMODATION. LEVEL OF EFFORT, ONE SENIOR SCIENTIST FOR PROJECT DURATION, 57 MONTHS, WITH ASSISTANCE OF ONE PERSON FROM ATP TO CDR, 18 MONTHS. BASIS: HEAO EXPERIENCE

05 DESIGN AND DEVELOPMENT. FOR EACH SUBSYSTEM THE ESTIMATE WAS REVIEWED AND, IF NECESSARY, MODIFIED ON THE BASIS OF FUNCTIONAL MANAGEMENT EXPERTISE.

051 STRUCTURES AND MECHANISMS. THE STRUCTURE DEVELOPMENT COSTS WERE DERIVED FROM THE ESTIMATES OF THE SPACE PLATFORM CENTRAL SECTION. MEC WAS CONSIDERED ABOUT 60% AS COMPLEX.

052 ELECTRICAL DISTRIBUTION AND CONTROL. THESE COSTS WERE DERIVED FROM THE DATA ON THE SPACE PLATFORM SYSTEM, WITH THE SOLAR ARRAY POWER CONTROL SYSTEM AND THE BATTERIES AND CHARGING SYSTEM DELETED. MEC WAS CONSIDERED ABOUT 30% AS COMPLEX.

053 THERMAL CONTROL. THESE COSTS WERE DERIVED FROM THE DATA ON THE SPACE PLATFORM SYSTEM WITH THE SP RADIATOR [illegible] OMMODATING HARDWARE DELETED. CONSIDERED ABOUT 30% AS COMPLEX.

054 COMMAND AND DATA MA[illegible]T. THIS SYSTEM IS CONSIDERED FUNCTIONALLY SIMILAR TO THAT OF THE VIKING LANDER B[illegible]GY INSTRUMENT AND COMPARABLE COSTS WERE USED.

055 GROUND SUPPORT EQUIPMENT. THE COSTS FOR THE GSE WERE CONSIDERED COMPARABLE TO THE APPROPRIATE MODEL 35 GSE. (USAF CONTRACT)

Figure 12. Bases of Estimates

06 MANUFACTURING. ALL ESTIMATES WERE REVIEWED AND, IF NECESSARY, MODIFIED ON THE BASIS OF FUNCTIONAL MANAGEMENT EXPERTISE.

061 STRUCTURE AND MECHANISMS. THE STRUCTURE MANUFACTURING COSTS WERE CONSIDERED ABOUT 65% OF THE COSTS OF THE SPACE PLATFORM CENTRAL SECTION. COSTS FOR ACQUISITION OF THE BERTHING ADAPTER ARE INCLUDED AND TAKEN FROM SP ESTIMATES.

062 ELECTRICAL DISTRIBUTION AND CONTROL. THE MANUFACTURING COSTS WERE CONSIDERED TO BE ABOUT 35% OF THE APPRORIATE SPACE PLATFORM COST ESTIMATES

063 THERMAL CONTROL. THE MANUFACTURING COSTS WERE CONSIDERED TO BE ABOUT 45% OF THE APPROPRIATE SPACE PLATFORM COST ESTIMATES.

064 COMMAND AND DATA MANAGEMENT. THE COSTS FOR MANUFACTURING WERE CONSIDERED COMPARABLE TO THOSE OF THE VIKING LANDER BIOLOGY INSTRUMENT AND USED WITHOUT CHANGE.

065 GROUND SUPPORT EQUIPMENT. THE COSTS FOR THE GSE WERE CONSIDERED COMPARABLE TO THE APPROPRIATE MODEL 35 GSE.

07 INTEGRATION AND TEST

071 SYSTEM INTEGRATION AND TEST. THESE COSTS WERE ESTIMATED TO BE ABOUT 25% OF THOSE FOR THE SP.

072 GSE AND FACILITY ACTIVATION. THE COSTS WERE CONSIDERED COMPARABLE TO THOSE FOR SPACECRAFT MODEL 35.

08 GROUND OPERATIONS

081 MEC/PAYLOADS INTEGRATION. THE COSTS FOR INTEGRATION AND TEST WERE CONSIDERED ABOUT TWICE THOSE FOR AN EARLY OFT PALLET OPERATION SUCH AS OAST-1.

082 STS INTEGRATION AND POST OPERATIONS SUPPORT. THE COSTS WERE CONSIDERED DIRECTLY COMPARABLE TO THOSE FOR OAST-1.

09 FLIGHT OPERATIONS

091 FLIGHT PLANNING. THE COST ESTIMATE WAS DERIVED AS ABOUT THE SAME AS THOSE FOR HEAO A.

092 FLIGHT SUPPORT. THE COST ESTIMATE WAS DERIVED AS ABOUT 50% OF THOSE FOR MATURE SPACELAB PAYLOAD POCC OPERATIONS.

093 CREW TRAINING. THE COST ESTIMATE WAS DERIVED AS ABOUT 10% OF SPACELAB PAYLOAD FLIGHT CREW TRAINING AND POCC OPERATOR TRAINING.

094 DATA PROCESSING. THE COST ESTIMATE WAS DERIVED AS A LEVEL OF EFFORT, 3 MEN FOR 3 MONTHS.

Figure 12. Bases of Estimates (Continued)

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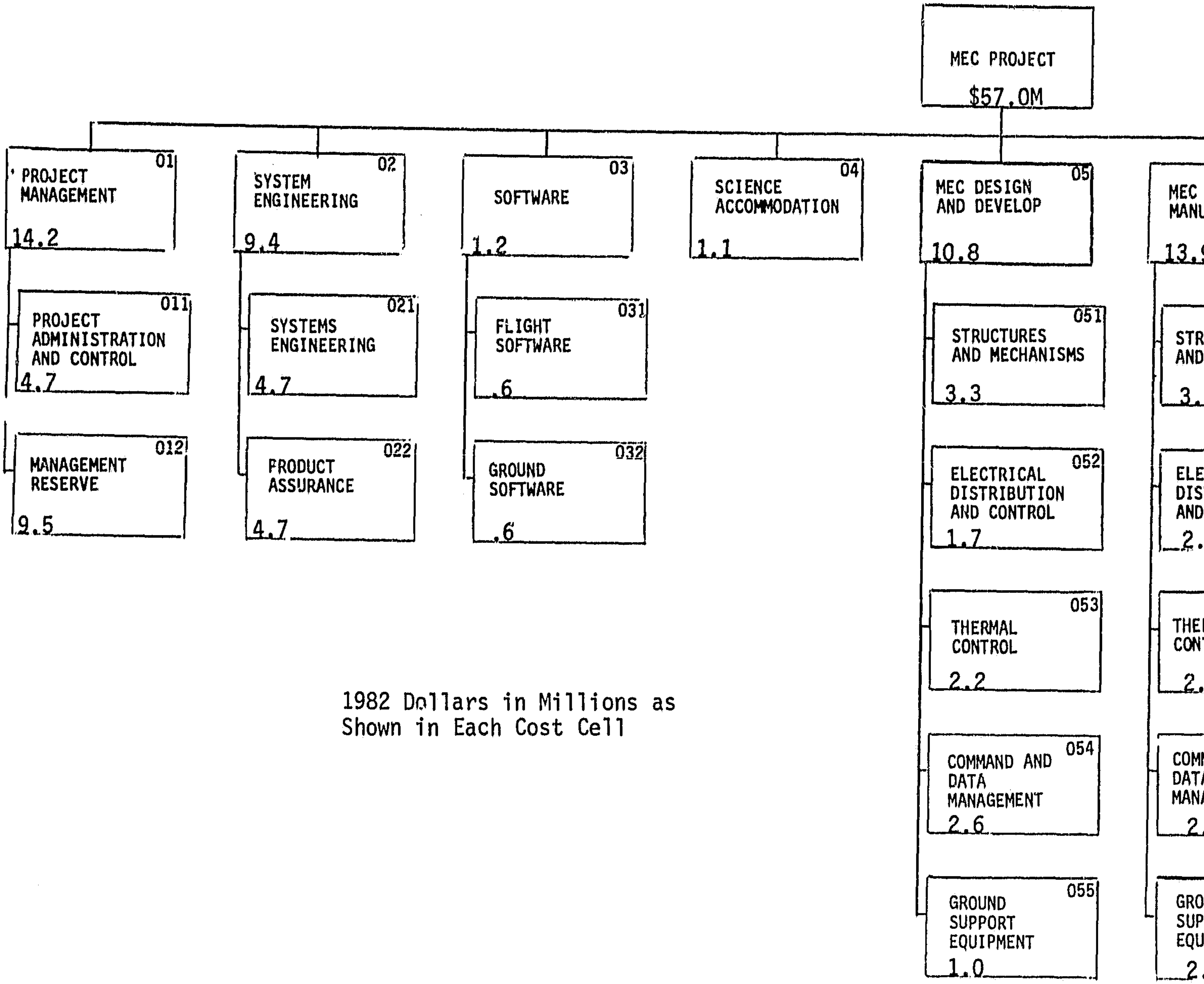

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Figure

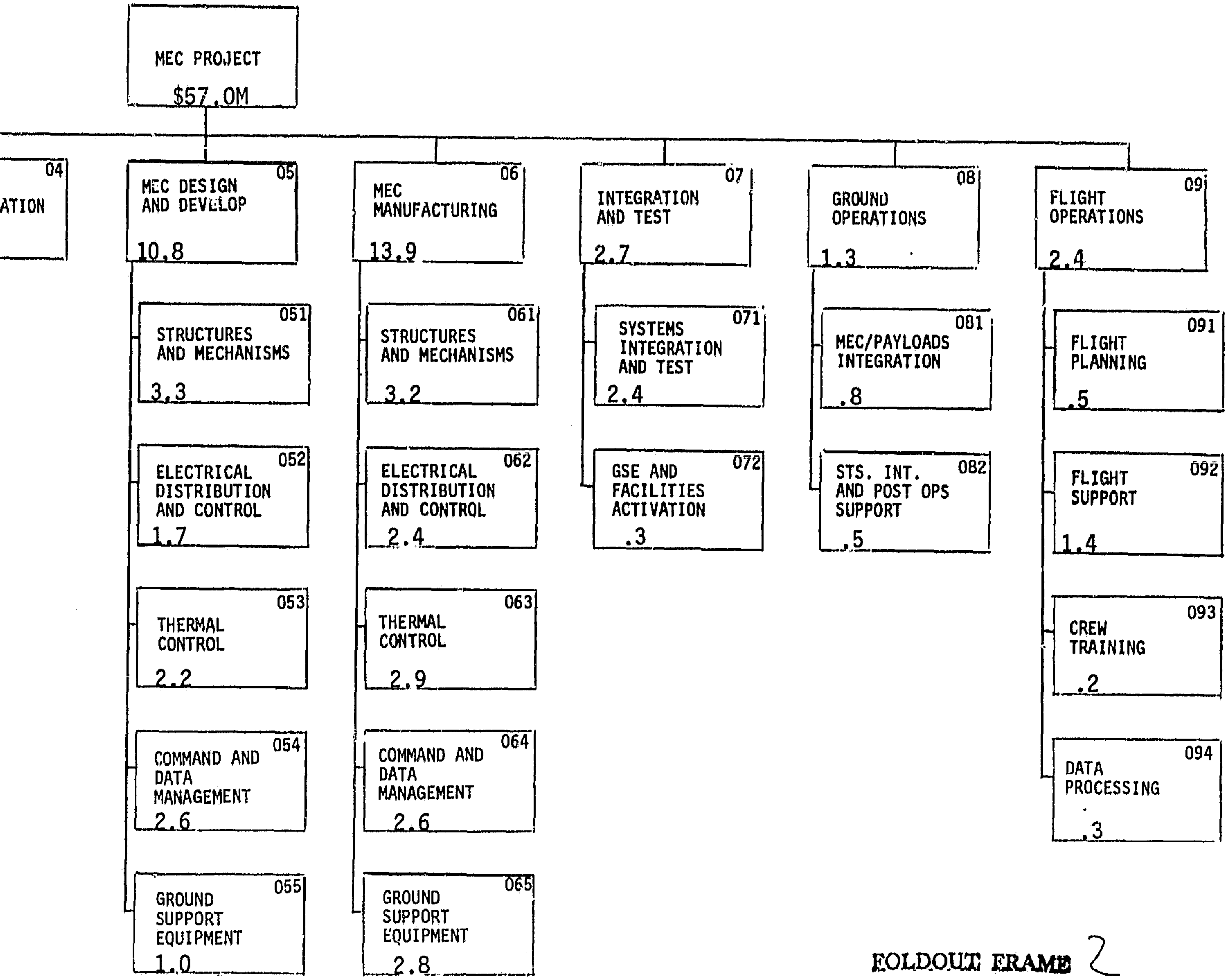

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Figure 13. MEC Project WBS Price Breakdown (1982 $, Millions)

WBS	DESCRIPTION	D&D	UNIT	OPERATIONS	TOTAL
01	PROJECT MANAGEMENT	7.8	4.9	1.5	14.2
	PROJECT ADMINISTRATION	(2.6)	(1.6)	(.5)	(4.7)
	MANAGEMENT RESERVE	(5.2)	(3.3)	(1.0)	(9.5)
02	SYSTEM ENGINEERING	7.4	1.6	.4	9.4
03	SOFTWARE	.6		.6	1.2
04	SCIENCE ACCOMMODATION	.5		.6	1.1
05	DESIGN AND DEVELOPMENT	10.8			10.8
06	MANUFACTURING	2.8	11.1		13.9
07	INTEGRATION AND TEST	.3	2.4		2.7
08	GROUND OPERATIONS			1.3	1.3
09	FLIGHT OPERATIONS	.8		1.6	2.4
	TOTAL	31.0	20.0	6.0	57.0

Figure 14. MEC Summary Price (1982 $, Millions)

WBS	DESCRIPTION	1984	1985	1986	1987	1988	TOTAL
01	PROJECT MANAGEMENT	4.2	6.6	4.2	2.1	.4	17.5
	PROJECT ADMINISTRATION	(1.4)	(2.2)	(1.4)	(.7)	(.1)	(5.8)
	MANAGEMENT RESERVE	(2.8)	(4.4)	(2.8)	(1.4)	(.3)	(11.7)
02	SYSTEMS ENGINEERING	4.0	3.4	1.6	1.5		10.5
03	SOFTWARE	.4	.8	.4			1.6
04	SCIENCE ACCOMMODATION	.4	.3	.3	.3	.2	1.5
05	DESIGN AND DEVELOPMENT	7.0	5.1	1.2			13.3
06	MANUFACTURING	.8	8.4	7.3			16.5
07	INTEGRATION AND TEST		.7	1.4	1.7		3.8
08	GROUND OPERATIONS			.3	1.2	.3	1.8
09	FLIGHT OPERATIONS		1.1	.3	1.4	.7	3.5
	TOTAL	16.8	26.4	17.0	8.2	1.6	70.0

Figure 15. MEC Price Spread (Then Year $, Millions)

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